USGS

## WATER RESOURCES RESEARCH GRANT PROPOSAL

**Title:** In situ testing of Integrated Grass Filter Strip-Permeable Reactive Barrier Systems for Groundwater Protection.

**Focus Areas:** NPP, TRT, WQL

**Keywords:** watershed management, water quality, contaminant transport, soil, erosion, phosphorus, bacteria, sorption, geochemistry, sanitation, eutrophication, sedimentation, water treatment

**Duration:** 3/01/00-2/28/01

**Federal funds requested:** 10,000

**Non federal funds requested:** 20,000

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**Congressional District**: Six

**Statement of critical water quality problems**

Grass filter strips (GFS) are best management practices recommended to protect sensitive surface and groundwater supplies. However, steep slopes often force producers to remove and convert extensive farmland areas to buffer filter strips. Furthermore, if extensive infiltration through filter strips occurs on shallow soils, there is significant potential for lateral flow along impermeable barriers such as bedrock, claypans, and fragipans that will result in poorly treated water being discharged to water supplies. Studies with filter strips have demonstrated that phosphorus and fecal bacteria, two significant agricultural contaminants affecting surface and groundwater quality, can circumvent treatment by filter strips because of rapid infiltration. An inexpensive, low maintenance strategy is required that can address these problems. Engineered permeable reactive barriers (PRB) have been effectively used to treat groundwater contaminants, but their use in agricultural systems where the infiltration of surface runoff through grass filters is exploited, has not been closely examined.

**Statement of the results, benefits, and information gained from research, and how they will be used**

We anticipate a successful test of the hypotheses that GFS, tile drains, and PRB can be integrated into a single design that will treat surface- and subsurface-derived pollutants. We will generate preliminary designs for such systems, and demonstrate the utility of various materials for pollutant removal. The benefits from this research will be recommendations for reduced filter strip lengths required to protect sensitive ground and surface water systems without sacrificing the effectiveness of grass filters as BMP's for groundwater protection. We project implementation of the pilot design on a larger scale. Specifically, we expect that integrated GFS-PRB systems, or modified systems, will be installed in several situations where pollutant transport could impact water quality, e.g. areas with cattle grazing, feedlots, agricultural runoff, and potential septic waste discharging into surface waters. We also anticipate that this research will lend itself to similar remediation of other pollutants (acid mine drainage, nitrate, pesticides).

**Nature, scope and objectives of research**

Grass filter strips (GFS) are recommended best management practices (BMP's) for protecting sensitive surface and groundwater supplies from agricultural pollutants such as phosphorus, bacteria, and pesticides. These filters remove pollutants by retarding surface runoff velocity and promoting sedimentation and infiltration. Most pollutant removal occurs within the first 1 or 2 meters of the grass filter. In deep, well-drained soils, biogeochemical processes in the vadose zone provide additional pollutant treatment. However, pollutants may enter water bodies when slopes are steep, when the landscape contains sinkholes, when dissolved constituents predominate, or during high rainfall events. Increasing the length of filter strips in response to these factors may not be effective, particularly if soils are shallow, highly structured, or nonreactive toward the pollutants. Coyne et al. (1998) demonstrated that in terms of fecal bacteria removal, only marginal improvements in runoff water quality occurred when 9.0-m wide filters replaced 4.5-m wide filters and McMurry et al. (1998), demonstrated that high numbers of fecal bacteria were transported through structured soil without effective filtration.

A relatively new technology, Permeable Reactive Barriers (PRB) has been demonstrated to attenuate a wide range of pollutants, including TCE (Ho et al., 1998), PCBs (Wang and Zhang, 1997), aniline (Khandelwal, 1998), nitrate (Schipper et al., 1997), and iron and trace metals (Benner et al., 1999). Recently, the technique has been proposed for phosphorus removal from wastewater disposal systems (Baker et al., 1998). A PRB is a passive in situ permeable wall situated in the landscape to receive pollutant plumes, and prepared from highly reactive materials selected for their ability to conduct pollutant removal via specific biogeochemical processes. Several types of materials have been utilized, including $Fe^{O}$ filings to mediate reductive chlorination of TCE and PCB, clay minerals to sorb TCE and aniline, Fe and Al oxides to sorb inorganic P, and organic matter to serve as an electron donor for denitrification and to reduce sulfate and promote sulfide precipitation of trace metals. The advantages of these systems are that they are highly efficient (>90% pollutant removal) and they require relatively little land area. The main disadvantage of the PRB is that pollutants must be directed into the PRB for treatment.

We propose that an integrated GFS-PRB would be an effective, low-cost, and low maintenance technology to remove a wide range of pollutants from agricultural runoff in sensitive groundwater systems. An integrated system would consist of a GFS and a subsurface water collection system that would divert pollutants into a PRB. The integrated system would have all the benefits of the separate systems and would overcome many of their deficiencies. For example, an integrated system could potentially reduce the amount of land required for GFS, and increase the pollution removal potential from agricultural activities. The level and types of treatment could be increased by installing sequential GFS-PRB-PRB' systems, which are customized for specific pollutant mixtures. Removal of fecal bacteria by PRB technology has not been reported.

The overall objective of the study is to develop and evaluate integrated GFS-PRB systems for phosphorus and bacteria removal in runoff from waste amended soils. Specific objectives include:

1) design and evaluate a tile drainage system to collect water from GFS; 2) determine the effectiveness of selected PRB materials to remove phosphorus and bacteria from agricultural drainage water; 3) determine the phosphorus and bacterial removal efficiency in GFS and integrated GFS-PRB systems.

**Methods, procedures, and facilities**

Objective 1. Hypothesis: Water infiltrating GFS can be effectively collected by a tile drainage system. This hypothesis will be tested by installing tile drains perpendicular and parallel to slope in a series of 10-m long GFS plots at UK's Spindletop Research Farm in Lexington. The tile drains will be installed at depths of 0.5-m in 2-m intervals beginning 1-m from the top of the filter in the perpendicular configuration. Two equidistant tile drains running the length of the GFS will be installed at a 0.5-m depth in the parallel configuration. At periodic intervals, known amounts of water will be added to the filters as surface runoff . The infiltrating water will be measured by tipping gages and the percentage of water collected by each tile drain will be calculated to determine the effectiveness of the number and spacing of drains. The optimal configuration will be installed in the final GFS-PRB design (Objective 3).

Objective 2. Hypothesis: PRB materials effectively sequester phosphorus and bacteria contained in manure-derived runoff This hypothesis will be tested by evaluating phosphorus and bacteria removal (obtained from manure extracts) in laboratory columns filled with potential PRB materials ($Fe^{O}$ filings, water treatment lagoon sludge, municipal compost) using a collection system similar to Gu et al. (1999). These are readily available materials expected to provide efficient pollutant removal. Fractions eluting from the columns will be collected and analyzed over time for total volume, total and dissolved P, and fecal bacteria. Sectioning of the columns will be used to determine the efficiency of pollutant removal as a function of column length. From these results, percent pollutant removal, retardation factors, and partition coefficients for each of the PRB systems will be determined. Experiments will be repeated at increasing loading rates of pollutants to evaluate the loading capacity of PRB materials. Depending on the results (e.g. low removal of one type of pollutant), sequential PRB systems will be evaluated for pollutant removal efficiency. The most effective PRB materials determined in this study will be utilized for the in situ integrated GFS-PRB system (Objective 3).

Objective 3. Hypothesis: Phosphorus and fecal bacteria will be effectively removed in GFS-and integrated GFS-PRB systems. This hypothesis will be tested by evaluating phosphorus and bacteria removal by GFS-PRB systems installed at Spindletop Research Farm. Tile drains will be installed in 10 m grass filters using the optimal configuration determined in Objective 1. Drains will be channeled to a centralized area leading into a PRB (or a series of PRBs) prepared from the most reactive materials determined in Objective 2. To compare the effectiveness of the PRBs, identical systems will be constructed containing a relatively inert material such as pea gravel in place of the PRB. Leachate collected from the + PRB and -PRB systems will be analyzed for total and soluble P and fecal bacteria. The difference in the concentrations of pollutants will be used to calculate the effectiveness of the GFS-PRB systems for pollutant removal. Replicated systems will be used to permit statistical evaluation of the data.

Spindletop is the site of ongoing GFS studies by Coyne. The study sites will be adjacent to a fixed irrigation supply on 9% slopes within 100 yards of a permanent outdoor laboratory facility. D'Angelo has a fully equipped biogeochemistry laboratory in the Agronomy department at UK for the analysis of P forms in leachate and establishing the column test of PRB materials. Coyne has a fully equipped soil microbiology laboratory in the Agronomy department at UK for the analysis of fecal bacteria in leachate from field and lab experiments.

| <u>Objective/Task</u> | <u>Month</u> |
|---|---|
| Tile Drain Configuration | 1 - 4 |
| Test of Reactive Materials | 2 - 6 |
| Integration of GFS-PRB | 5 - 9 |
| Final Report | 10 - 12 |

**Related research**


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Wang, C. and W. Zhang. Synthesizing nanoscale particles for rapid and complete dechlorination of TCE and PCBs. Environ. Sci. Technol. 31 :2154-2156.